The average flow of water in the river as it enters Oklahoma near Watts is 703 cfs which increases to 1095 cfs as the river reaches Tahlequah (USGS database, period of record 10/81 - 09/91), shortly after which it flows into Lake Tenkiller. The major tributaries of the Illinois River in Oklahoma are the Baron Fork River, Caney Creek, and Flint Creek.

The river is classified as a state scenic river from the Lake Frances Dam down to its confluence with the Baron Fork, a distance of approximately 70 miles. A 35 mile segment of the Baron Fork River and a 12 mile segment of Flint Creek are classified as scenic rivers upstream from their confluence with the Illinois River. The rest of the river basin in Oklahoma consists of Tenkiller Ferry Reservoir and a short segment downstream of the dam to its confluence with the Arkansas River.

The watershed lies with the Ozark Highlands and Arkansas Valley Ecoregions. The majority of the watershed in Oklahoma is in the Ozark Highland Ecoregion. This ecoregion is characterized by oak-hickory forests on well-drained soils of slopes, hills, and plains. Trees are of medium height (20 to 60 feet or 6 to 18 meters) with a relatively open canopy which allows a thick understory of slow-growing shrubs and trees. Areas of exposed rock are common. Blackjack oak, post oak, white oak, black hickory, and winged elm are the common overstory trees, and coralberry, huckleberry, and sassafras are representative of the understory. A taller forest community is found in protected ravines and on moist or north-facing slopes where soils are deeper and well drained. These forests are 60 to 90 feet (18 to 27 meters) high and consist of an overstory of sugar maples, white oaks, chinquapin oak, and hickory, with an understory of redbud, flowering dogwood, pawpaw, spice bush, sassafras and coral berry. Mosses, ferns, and liverworts are abundant on the moist forest floor. Bottomland hardwood forests of oak, sycamore, cottonwood, and elm exist along floodplains of larger streams. Elevations range from 1477 to 640 NGVD. Soils are derived mainly from chert and limestone.

The southern-most section of the watershed lies in the Arkansas Valley Ecoregion. This ecoregion forms the break between the Ozark Highlands and the Ouachita Mountains. Dry forests of short (50 feet or 15 meters tall) post oak, blackjack oak, and scattered hickories with significant cover of tallgrass prairie plants and little or no understory dominate rugged areas and extend into the plains. Shortleaf pine savannas occupy ridgetops of this ecoregion. Tallgrass prairie communities of bluestems, Indian grass, switchgrass, and other tall grasses dominate the broad valley, interspersed with wildflowers, dry upland forests, and bottomland hardwood forests along streams. These tall (100 feet or 30 meters) bottomland forests consist of oak, elm, and hackberry and usually have two or three levels of trees below the overstory. Grape, poison ivy, and greenbriar vines are common in the understory. Elevations range from 1000 to 460 NGVD.

Major soils within the basin are in the Captina, Clarksville, Enders, Jay, Linker, Mountainberg, Nella, Nixa, Noark, Razort, Steprock, and Waben series (USDA 1992). The majority of the higher reaches of the watershed are Clarksville-Nixa-Noark; deep, loamy cherty soils moderately to well drained, moderately to rapidly permeable. These soils are derived from cherty limestone. Soils in the vicinity of Lake Tenkiller are Enders-Linker-Mountainberg-Nella; deep, loamy, gravelly or stony soils derived from acid sandstone, siltstone, and shale. These well drained soils range from very slowly permeable to moderately rapidly permeable. The population of the basin in Oklahoma is approximately 50,000 - 60,000 based on 1995 estimates (OWRB 1996). The number of people below the poverty level in the four Oklahoma counties is higher than the state average (**Table 1**). The education attainment of the four Oklahoma counties was below the state average except in Cherokee County where Northeastern Oklahoma University is located (**Table 2**).

The dominant industry in the basin is agriculture, primarily poultry and livestock. **Table 3**

Table 1. Population Percent Below Poverty Level (USDA 1992).

County/State	Persons	Families
Statewide-Oklahoma	13.4	10.3
Adair	27.6	22.1
Cherokee	22.2	18.3
Delaware	21.4	16.7
Sequoyah	20.1	16.3

Table 2. Education Statistics, 1980 (USDA 1992).

	Percent > 12 years	Percent > 16 years
Oklahoma-Statewide	66.0	15.1
Adair	45.1	8.7
Cherokee	56.2	17.8
Delaware	52.8	7.3
Sequoyah	48.2	8.3

displays rankings of Oklahoma counties in agriculture. Livestock is not the only agricultural activity in the basin. Although only a small percentage of the watershed is cropped, intensive crops such as vegetables, strawberries, fruit orchards, and nurseries are an important part of the economy in Cherokee and Adair Counties.

Table 3. Oklahoma County Rankings in Agricultural Productivity (USDA 1992).

	County Ranking			
	Adair	Cherokee	Delaware	Sequoyah
Cash Receipts from Agricultural Products Sold	5	4		
Swine Production	2		1	
Number of Milk Cows in OK	2		4	

The watershed also has a significant recreation industry. Annual visitation to the river is about 400,000 with about 180,000 taking advantage of the floating opportunities (OSRC 1998). Lake Tenkiller also has one of the few and most noteworthy scuba diving opportunities in the state. Excellent fishing opportunities are also available on the Illinois River, Lake Tenkiller, Baron Fork Creek, and Flint Creek with over 68 game species available (OSRC 1998).

Land use in the Oklahoma portion of the watershed is illustrated in **Table 4** and **Figure 3.** Forest land (deciduous, evergreen, and mixed) makes up approximately 57 percent of the total watershed area. Agricultural land makes up approximately 38 percent of the total watershed area (A more specific view of some agricultural land is shown in a later section of this report. **Figure 12** displays locations of confined animal feeding operations in the watershed). Urban, transportation, and utilities areas make up approximately 3 percent of the watershed.

Table 4. Land Use of the Illinois River Basin in Oklahoma (1970-1980 USGS).

Land Use Category	Land Use Code	Area (m^2)	Area (mi^2)
Residential	11	46767802.33	18.06
Commercial and Services	12	8549757.01	3.30
Transportation, Commerce, Utilities	14	1015323.63	0.39
Other Urban or Built-up Land	17	5482459.55	2.12
Cropland & Pasture	21	813912103.00	314.25
Orchards, Nurseries, Ornamental Horticulture	22	5026276.57	1.94
Confined Feeding Operations	23	6594362.41	2.55
Other Ag. Land	24	1453287.53	0.56
Deciduous Forest	41	825790490.20	318.84
Evergreen Forest	42	4338258.94	1.68
Mixed Forest	43	413416922.80	159.62
Reservoirs	53	48709240.11	18.81
Nonforested Wetland	62	1872074.13	0.72
Beaches	72	149858.13	0.06
Strip mines, Quarries, Gravel Pits	75	86894.26	0.03
Transitional Areas	76	14801112.99	0.57

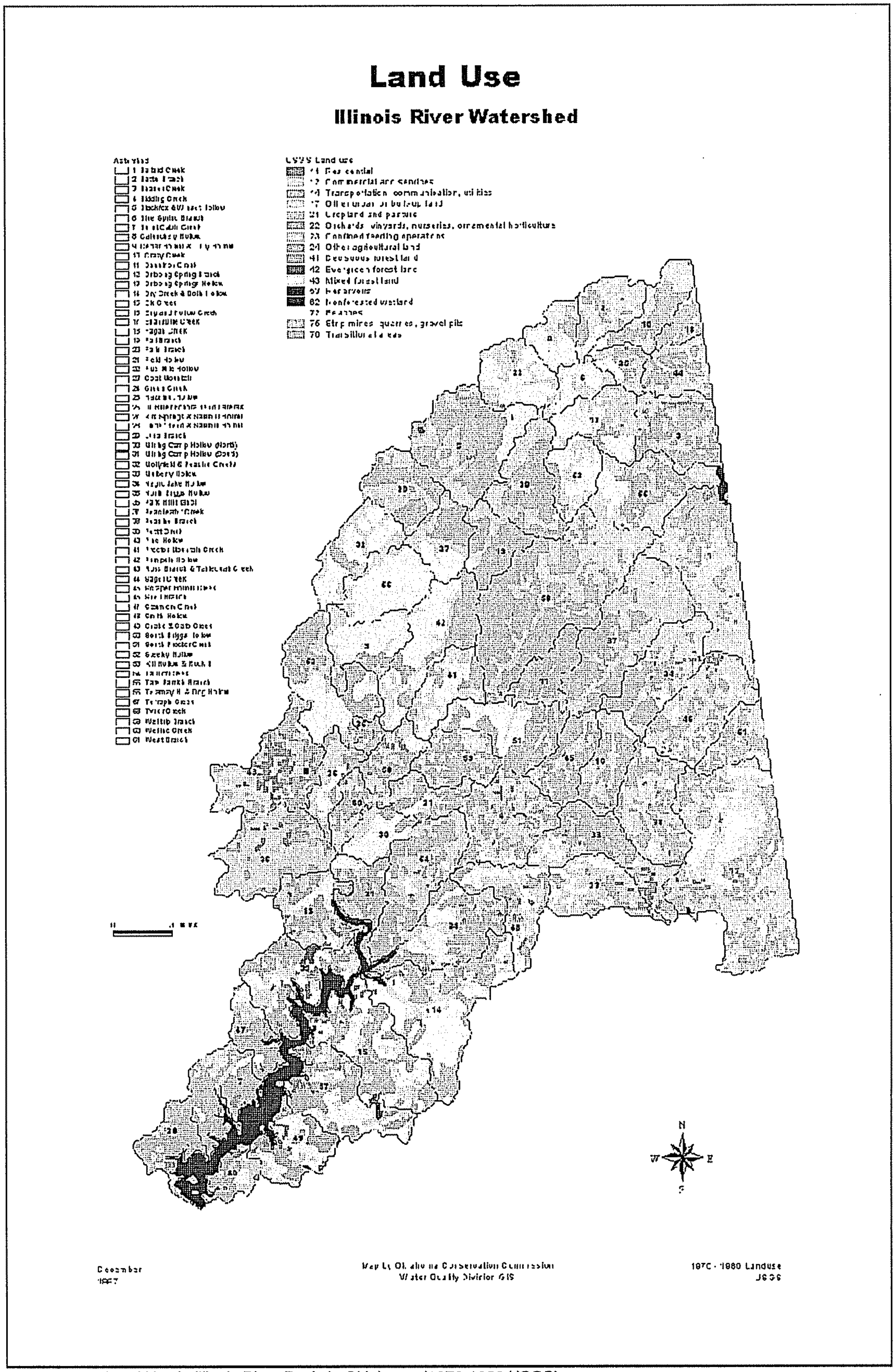

Figure 3. Land Use in Illinois River Basin in Oklahoma (1970-1980 USGS).

PROBLEMS AND CONCERNS

The Illinois River Basin has received as much attention as any other water resource in recent Oklahoma history. Most of this attention has focused on the perception that river quality has degraded over the past decade as a result of point and nonpoint source discharges.

Although some of the discussion of river degradation has been based upon public opinion, a considerable body of evidence indicates the river contains excessive levels of nutrients. In addition, studies in Lake Tenkiller indicate the upper portions of the lake have become eutrophic as evidenced by frequent and extensive algal blooms. Evidence to-date indicates that the source of the nutrients are both point and nonpoint source in nature with each contributing different proportions, dependent upon season and river flow volume.

Recent studies suggest a lesser known but perhaps even greater problem in the river and its tributaries is bank erosion. Bank erosion, primarily due to poor riparian management such as clearing native vegetation and overuse by livestock, is occurring at an alarming rate, contributing sediment and gravel to the streams and river. This causes shallowing and widening of the channels, resulting in loss of crucial habitat for benthic macroinvertebrate and fish populations. Although this degradation is most evident in the river and its tributaries, evidence will become increasingly apparent in the upper reaches of Lake Tenkiller as mud flats develop and turbidities increase.

Much of the understanding of problems in the basin has been generated through government projects and programs. While the data indicate that there are water quality problems, another important measure of the river's health is the public's opinion, especially in the eye of those who live in the river basin. Public opinion is particularly important when solutions for improving river quality are considered.

In order to develop an understanding of the public's opinion concerning the quality of water in the Illinois River, a series of public meetings were held in 1992. Each meeting focused on a different interest group in order to develop an understanding of that group's thoughts about the river. Each group was asked to identify and rank problems, identify and prioritize causes, and generate solutions for priority problems. The groups which met were decision makers (Indian tribes, municipalities, state government), nursery producers, recreational industry, and agricultural producers.

Taken together the groups agreed that the following pollution problems had occurred in the river:

Changes in fish populations
Wider and shallower river
Excessive growth of algae
Murky water

Stream bank erosion
Waste problems

The groups added that the following were problems and causes (listed in no particular order or relationship to one another):

Problems	Causes
recreation	nonpoint source pollution
poultry and agricultural waste	dumping of raw/treated sewage
open sewers	lack of education about wastes
loss of riparian areas	inadequate recreation facilities
sediment load from roads	development and growth
public apathy	waste dumping
confined animal operations	poor enforcement of trash laws
urban runoff	agricultural runoff
	solid waste
	tourism/recreation

Although some of these groups have specific interests in production activities within the basin, there was a noticeable lack of finger pointing. Each group recognized that the problems and causes were many and that contributions from all areas must be addressed. There was general agreement among the groups concerning pollution problems are their causes, although the prioritization of these factors varied.

Despite the extensive efforts to study and understand the condition of the river and the sources of pollution, no basin-wide plan to address pollution sources has been adopted. It has been recognized by all parties that any attempt to improve river quality must be based upon a comprehensive approach covering the entire basin. While this would seem to be an obvious approach to the problem, recent political history indicates that a diversity of opinion exists concerning pollution sources and their relative contribution to the problem.

WATER QUALITY STUDIES

Numerous projects have measured water quality of the Illinois River. These projects have not been coordinated to cover all areas of concern, nor have they been conducted in a consistent manner; however, despite these limitations, a substantial amount of information exists upon which to characterize river water quality. Many of these studies were reviewed and their findings condensed in a report titled "Evaluation and Assessment of Factors Affecting Water Quality of the Illinois River in Arkansas and Oklahoma" which was completed as a joint effort between Oklahoma State University and the University of Arkansas in 1991. Other important works which have been completed and are discussed in this document include a 1992 study which characterizes the natural, physical, and human resources of the basin (USDA et al.), a study of the quality of water from small streams which feed the river within Oklahoma (Oklahoma Conservation Commission, (OCC)), a report reviewing ten years of data collection on the river and major tributaries (Oklahoma Scenic Rivers Commission), and a Clean Lakes Phase I Diagnostic and Feasibility Study on Lake Tenkiller (Oklahoma Water Resources Board and Oklahoma State University). The following section will summarize the findings of these studies. The intent of this section is to familiarize the reader with some of the specific water quality issues which are important in the basin and is not intended to deal with all of the information which has been collected.

A. ARKANSAS/OKLAHOMA JOINT RIVER STUDY

The most thorough compilation of data from the Illinois River Basin is contained in the "Oklahoma State University (OSU) and University of Arkansas Cooperative Report on Evaluation and Assessment of Factors Affecting Water Quality of the Illinois River in Oklahoma and Arkansas".

The purpose of this report was to gather all information concerning water quality in the Illinois River Basin into a single document and to interpret the results. This is a lengthy document to which the reader is referred if additional or more detailed information is required. One of the major areas of focus was the identification of trends in the data over time and space which are discussed in the following sections.

1. Total Phosphorus

Spatial trends - statistically significant decrease in concentration from the Arkansas border to Tahlequah.

- statistically significant increase in concentration below Osage Creek.

Temporal trends - statistically significant increases at nine of seventeen sites.

Mean values were in excess of the recommended level of 0.05 mg/L at all sites with some being exceptionally high. The data summary for phosphorus is included in **Table 5**.

Table 5. Summary Statistics for Illinois River Sampling Stations for Total Phosphorus.

Station ID	Site #	n (months)	Total Phosphorus as P (mg/L)		
			Mean	Median	SD
USGS 07195000	1	134	1.082	0.755	0.927
SR 0.5	2	14	0.313	0.295	0.100
USGS 07195500	3	170	0.293	0.198	0.313
SR 1	4	64	0.265	0.233	0.151
SR 2	5	66	0.225	0.192	0.176
USGS 07195860	6	117	1.496	0.820	1.021
USGS 07196000	7	127	0.188	0.172	0.090
SR 3	8	66	0.211	0.184	0.098
SR 4	9	66	0.201	0.170	0.081
SR 4.5	10	14	0.200	0.187	0.090
SR 5	11	66	0.181	0.133	0.295
USGS 07196500	12	127	0.130	0.100	0.133
SR 6	13	62	0.845	0.387	0.936
SR 6.3	14	11	0.154	0.118	0.074
USGS 07197000	15	126	0.079	0.044	0.102

2. Nitrite/Nitrate

The data for summary is included in **Table 6**.

Spatial trends - statistically significant decrease in concentration from the Arkansas border to Tahlequah.

- increase in concentration below Osage Creek.

Temporal trends - statistically significant increases at most sites.

Mean values were high at all sites and exceeded recommended values of 1.0 mg/L.

Table 6. Summary Statistics for Illinois River Sampling Stations for Total Nitrogen.

Station ID	site #	n (months)	Total Nitrogen as N (mg/L)		
			Mean	Median	SD
USGS 07195000	1	108	4.081	4.000	1.262
SR 0.5	2	14	1.843	1.625	0.749
USGS 07195500	3	110	1.510	1.200	0.873
SR 1	4	64	1.819	1.800	0.966
SR 2	5	66	1.673	1.400	1.491
USGS 07195860	6	80	2.888	2.250	1.031
USGS 07196000	7	98	1.291	1.100	0.679
SR 3	8	66	1.480	1.475	0.778
SR 4	9	66	1.459	1.300	0.797
SR 4.5	10	14	1.357	0.417	0.647
SR 5	11	66	1.293	1.200	0.953
USGS 07196500	12	96	1.052	0.800	0.718
SR 6	13	62	2.245	1.600	1.619
SR 6.3	14	10	1.266	1.200	0.550
USGS 07197000	15	98	0.914	0.700	0.628

3. Nitrogen/Phosphorus Ratios

Nitrogen/phosphorus ratios are much lower from the river main stem and main tributaries than for the smaller tributaries. It can be seen by comparing the data from the two data sets that nitrogen values are relative similar, while phosphorus values are much higher at the main stem sites. This might indicate that point sources of phosphorus are playing a major role in maintaining high river values.

4. Nutrient Sources

Considerable attention was paid to the identification of nutrient sources, especially in regard to phosphorus loading. It was estimated that phosphorus loading from point versus nonpoint sources was approximately equal during low flow conditions but that nonpoint sources exceeded point sources during normal or high flows.

In terms of annual loading of phosphorus it was estimated that the loading at the upper end of Lake Tenkiller was 21% from point sources and 79% from nonpoint sources. Total point source loading of phosphorus was estimated to account for 12% of the Oklahoma total.

5. Effects on Lake Tenkiller

The primary conclusion that was drawn from the data was that phosphorus loading exceeds the levels, as predicted by Vollenweider's model, that would cause Lake Tenkiller to become eutrophic.

B. ILLINOIS RIVER COOPERATIVE RIVER BASIN RESOURCE BASE REPORT

The objectives of this report were to better define water quality problems of the Illinois River basin, to prioritize watersheds needing project action to improve water quality, and to develop separate water quality project plans on high priority watersheds in Arkansas and Oklahoma. This report covers a wide variety of subjects, including natural resources, human resources, problems, concern, ongoing activities, and recommendations. The main outputs of the report include three systems for designating priority watersheds developed by three different agencies; Arkansas Soil Conservation Service (SCS), Oklahoma SCS, and the Oklahoma Conservation Commission (OCC). These results are seen in **Table 7**, **Table 8**, and **Table 9**. The Arkansas SCS system was developed using potential nonpoint agriculture source data, land use, municipal water supply locations, benthic data, and chemical data. The Oklahoma SCS system was developed using potential nonpoint agriculture source data, land use, and watershed size. The OCC system was developed using potential agricultural nonpoint source data and water sampling data. The highest priority watersheds for both states are generally low order streams or headwater streams. Many of the highest priority subwatersheds in Oklahoma were tributaries of the Baron Fork Creek.

The report also included recommendations for improving environmental quality of the basin. Water quality plans were completed for Upper Osage, Little Osage, and Clear Creeks in Arkansas in 1992, and for Shell and Ballard Creeks in Oklahoma in 1991. These plans suggested voluntary adoption of conservation practices by producers with technical assistance provided by the SCS, cost share incentives provided by the ASCS, and a strong education and information program as the preferred methods to correct and prevent agricultural source nonpoint source pollution. Additional recommendations made in the report based on a review of studies summarized in the report included:

Table 7. Nonpoint Pollution Potential Rankings: Arkansas SCS Priority Watersheds

Rank	Watershed	County	Score	Map #
1	Clear Creek	Washington	3202	221
2	Upper Osage	Benton	3197	352
3	Little Osage	Benton	3186	375
4	Blair Creek	Washington	2684	420
5	Baron Fork of Ill. River	Washington	2400	820
6	Spring Creek	Benton	2281	380
7	Upper Moores Creek	Washington	2279	440
8	Ballard Creek	Washington	2163	081
9	Flint Creek	Benton	2134	610
10	Upper Illinois River	Washington	2094	140
11	Lower Osage Creek	Benton	2082	351
12	Ruby Creek	Washington	2037	120
13	Gum Springs Creek	Benton	NG	520
14	Fish Creek	Washington	NG	310
15	Little Flint Creek	Benton	NG	620
16	Wildcat Creek	Washington	NG	330
17	Galey Creek	Benton	NG	360
18	Hamstring Creek	Washington	NG	220
19	Wedington Creek	Washington	NG	720
20	Cincinnati Creek	Washington	NG	710
21	Lower Moores Creek	Washington	NG	430
22	Goose Creek	Washington	NG	130
23	Fly Creek	Washington	NG	840
24	Kinion Creek	Washington	NG	450
25	Brush Creek	Washington	NG	340
26	Muddy Fork of Ill. River	Washington	NG	410
27	Sager Creek	Benton	NG	630
28	Lick Branch	Benton	NG	371
29	Robinson Creek	Benton	NG	320
30	Gallatin Creek	Benton	NG	550
31	Evansville Creek	Washington	NG	830
32	Lake Wedington	Washington	NG	110
33	Puppy Creek	Benton	NG	392
34	Cross Creek	Benton	NG	391
35	Frances Creek	Benton	NG	510
36	Chambers Creek	Benton	NG	530
37	Pedro Creek	Benton	NG	540

NG: not given in report.

Table 8. Illinois River Cooperative River Basin Priority Watersheds, Oklahoma SCS.

Rank	Watershed	County	Rank	Watershed	County
1	Tyner Creek	Adair	31	Pumpkin Hollow	Adair
2	Peacheater Creek	Adair	32	Mulberry Hollow	Cherokee
3	Ballard Creek	Adair	33	Dry Creek and Bolin Hollow	Adair, Cherokee Sequoyah
4	Green Creek	Adair	34	Cedar Hollow & Tully Hollow	Cherokee
5	Tahlequah & Kill H., Rock Branch	Adair	35	Field Hollow	Cherokee, Adair
6	Battle Branch Creek	Delaware	36	Dripping Springs	Adair, Delaware
7	Shell Creek	Adair	37	Smith Hollow	Adair
8	Evansville Creek	Adair	38	Goat Mountain	Adair
9	Mollyfield, Peavine Hollow	Cherokee	39	Walltrip Branch	Adair, Cherokee
10	Scraper Hollow	Adair	40	Tailholt Creek	Adair, Cherokee
11	Peavine Branch	Adair	41	Mining Camp Hollow North	Cherokee
12	England Hollow	Adair	42	Linder Bend & Saw Mill Hollow	Sequoyah
13	Tate Parrish	Adair	43	Luna Branch	Adair
14	Bidding Creek	Adair	44	Pettit Branch	Cherokee, Sequoyah
15	South Briggs	Cherokee	45	Pine Hollow	Sequoyah
16	West Branch	Adair	46	Park Hill Branch	Cherokee
17	Sager Creek	Delaware	47	South Proctor Branch	Adair
18	Hazelnut Hollow	Delaware	48	Snake & Cato Creek	Sequoyah
19	Blackfox, Winset Hollow	Adair, Cherokee Delaware	49	Elk Creek	Cherokee, Sequoyah
20	Bluespring Branch	Cherokee	50	Terrapin Creek	Sequoyah
21	Fagan Creek	Delaware	51	Mining Camp Hollow South	Cherokee
22	Crazy Creek	Delaware	52	Burnt Cabin Creek	Sequoyah
23	Negro Jake Hollow	Adair, Cherokee	53	Sizemore Creek	Cherokee, Sequoyah
24	Fall Branch	Adair	54	Proctor Mountain Creek	Adair, Cherokee
25	North Briggs Hollow	Cherokee	55	Ross Branch & Tahlequah Cr.	Cherokee
26	Calunchety Hollow	Delaware	56	Kirk Springs & Sawmill Hollow	Adair, Cherokee
27	Falls Branch	Cherokee	57	Dripping Springs Hollow	Cherokee
28	Steeley Hollow	Cherokee	58	Dennison Creek	Adair
29	Beaver Creek	Adair, Delaware	59	Welling Creek	Cherokee
30	Five Mile Hollow	Delaware	60	Telemay & Dog Hollow	Cherokee

Table 9. Illinois River Cooperative River Basin Priority Watersheds - OCC.

Prioritization Based on Phosphorus			Prioritization Based on Nitrogen		
HU*	Name	Rank	HU*	Rank	Name
509	Tyner (L&U)		512	Peacheater	
330	Kill, Rock & Tahlequah		337	Ballard	
337	Ballard (L)		610	Fagan	
609	Sager	1	604	Battle Branch	1
518	Shell		518	Shell	
604	Battle Branch		514	England	
514	England		315	Mollyfield	
325	Fall Branch (East)		606	Hazelnut	
333	Tate Parrish		521	West	
610	Fagan		609	Sager	
521	West		515	Green	
504	Field	2	509	Tyner (L&U)	2
321	Fall Branch		333	Tate Parrish	
310	Cedar & Tully		330	Kill, Rock, & Tahlequah	
513	Scraper		607	Crazy	
323	Black Fox & Winset		603	Calunchety	
519	Peavine (E&W)		513	Scraper	
607	Crazy		519	Peavine (E & W)	
331	Dripping Springs Br.		404	Bidding	
315	Mollyfield	3	334	Beaver	3
309	Pumpkin		331	Dripping Springs Br.	
603	Calunchety		520	Evansville (L&U)	
512	Peacheater		325	Fall Branch (E)	
606	Hazelnut		602	Five Mile	
408	Goat		402	Negro Jake	
219	Bolin & Dry		408	Goat	
507	Walltrip Branch		227	Parkhill	
334	Beaver	4	409	Mulberry	4
520	Evansville (L&U)		323	Black Fox & Winset	
227	Parkhill		312	Steeley	
403	Tailholt		326	Luna	
404	Bidding		507	Walltrip Branch	

HU* Hydrologic Unit Number

Table 9. Continued.

Prioritization Based on Phosphorus			Prioritization Based on Nitrogen		
HU	Name	Rank	HU	Rank	Name
302	Ross & Town Branch		407	Smith	
515	Green		309	Pumpkin	
510	South Proctor (E&W)		510	South Proctor (E&W)	
204	Linder Bend	5	403	Tailholt	5
401	Negro Jake		321	Fall Branch	
213	Terrapin		310	Cedar & Tully	
225	Mining Camp South		502	Mining Camp North	
215	Sizemore		302	Ross & Town Branch	
218	Elk		216	Petit	
207	Burnt Cabin		212	Pine	
326	Luna		504	Field	
407	Smith	6	219	Bolin & Dry	6
312	Steeley		605	Bluespring Branch	
602	Five Mile		506	South Briggs Hollow	
216	Petit		509	Proctor Mountain	
212	Pine		307	North Briggs Hollow	
409	Mulberry		225	Mining Camp South	
502	Mining Camp North		215	Sizemore	
506	South Briggs Hollow		209	Cato & Snake	
605	Bluespring Branch	7	204	Linder Bend	7
309	Kirk Spr./Sawmill		511	Dennison	
209	Cato & Snake		319	Kirk Spr./Sawmill	
307	North Briggs Hollow		218	Elk	
314	Dog & Telemay		213	Terrapin	
	Missing Data			**Missing Data**	
226	Dripping Spr. Hollow		207	Burnt Cabin	
508	Proctor Mountain		314	Dog & Telemay	
511	Dennison		226	Dripping Spr. Hollow	
503	Welling Creek		503	Welling Creek	

1. Continued support of governor's animal waste task force in Arkansas as means to coordinate agency programs and projects and identify inadequacies, overlap, and/or conflict in animal waste regulations or guidelines.
2. A complete review of existing regulation, legislation, and agency policies concerning animal waste in Oklahoma to determine deficiencies.

3. Comprehensive study of groundwater quality coordinated with nonpoint source programs where possible and continued support of ongoing groundwater monitoring.
4. Continue to streamline and develop new practices to protect water quality.
5. Further develop and support technology to compost and market poultry litter as a soil improvement.
6. Continue to develop water quality farm plans, particularly in priority watersheds in response to local concerns and needs.
7. Develop an intensive educational program to educate the public, landowners, and operators about the extent of the nonpoint source pollution problem, the potential to their operation to contribute to the problem, and sources of available assistance.
8. Basin residents and government agencies need to be innovative in developing and implementing measures to protect, improve, or enhance water quality in the basin by:
   ! evaluating existing programs, laws, and policies to determine potential contributions to water quality improvement and necessary modifications and expansions.
   ! identification of need and development of new programs
   ! establishing an effective monitoring program
   ! Establishment of a governor's advisory group in Oklahoma to support water quality issues and provide a forum for economic growth while minimizing impacts on the environment.
9. Phosphorus discharge limits based on the cumulative phosphorus capacities in Lake Tenkiller and the Illinois River should be included in all point source discharge permits.

C. OKLAHOMA SCENIC RIVERS COMMISSION - RIVER TREND STUDY

The data from samples collected by the Oklahoma Scenic Rivers Commission was analyzed to determine existing and historic water quality conditions, as well as any trends which might be present. An excellent historic data base exists for several sites where monthly samples have been collected since December 1980. This report covers the analysis of approximately 120 samples collected between 12/80 and 10/92 from each of the following sites:

Camp Paddle Trails
Fiddlers Bend
Chewey Bridge
Round Hollow
Echota Bend
Illinois River below the Tahlequah Creek confluence
Flint Creek
Sager Creek

Other sites have been sampled less frequently due to changes in sample site location and other factors; therefore, less data exists from these sites, and that which exists may be temporally disrupted or may cover a limited duration. Despite these limitations, some of this data is very useful in interpreting stream conditions. This includes the following sites:

Peavine Hollow
No Head Hollow
Baron Fork
Hwy 59 bridge (Arkansas)
Hwy 16 bridge (Arkansas)
Illinois River above Osage Creek (Arkansas)
Illinois River above Flint Creek

1. Trend Analysis

Method I

Trend analysis is used to determine long-term changes in water quality. There are several methods available for accomplishing this; however, in this report the Seasonal Kendall Tau test was performed utilizing the WQSTAT software package developed by Woodward-Clyde and Colorado State University.

Taken as a whole, the data from the long-term sites show few trends and those trends which exist are of a low magnitude. This indicates that there has been little change in the quality of water at theses sites over the almost twelve year sampling period. It should be mentioned that there is a high degree of variance in the data, that is, values fluctuate widely from month to month. Some of this fluctuation is due to changes in river volume; therefore, if values could be looked at in terms of loading, the data would probably be more uniform. The wide degree of data variance probably masks some trends. Trends which were found to be statistically significant (95% confidence level) are listed in **Table 10**.

The best overall conclusion that can be drawn from this data is that chemical oxygen demand (COD) appears to be dropping at several sites, but that turbidity seems to be increasing. Given the amount of variance in the data, these analyses are largely un-satisfactory; therefore, long-term changes will be looked at in another fashion.

Table 10. Temporal trends found in Scenic Rivers Commission Study (1980-1992).

Site	Trend	Parameter
Camp Paddle Trails	positive	turbidity
Fiddlers Bend	negative	COD
Fiddlers Bend	negative	phosphorus
Chewey Bridge	negative	COD
Chewey Bridge	positive	phosphorus
Chewey Bridge	positive	turbidity
Round Hollow	negative	COD
Echota Bend	negative	COD
Echota Bend	positive	turbidity
IR blw. Tahlequah Cr.	negative	COD
IR blw. Tahlequah Cr.	positive	turbidity

Method II

Another way that the time sequence data can be looked at is to compare average values during early years to that of later years. In this case data averages for the first two years have been compared to those of the last two years of sample collection as listed in **Table 11**.

Table 11. Water Quality in the Illinois River Basin (1980/81 vs. 1991/92).

Site	Date	COD	TN	TP	TSS	TURB.
Paddle Trails	80/81	10.6	2.02	0.253	17.6	11.1
	91/92	6.6	2.49	0.236	20.1	12.3
Fiddlers Bend	80/81	7.1	1.78	0.223	9.5	4.1
	91/92	3.7	2.22	0.170	6.4	3.9
Chewey Bridge	80/81	6.3	1.62	0.195	7.2	4.4
	91/92	4.5	1.98	0.170	4.3	5.0
Round Hollow	80/81	6.6	1.71	0.196	6.3	3.2
	91/92	4.0	2.02	0.166	5.2	3.1
Echota Bend	80/81	6.8	1.40	0.090	5.4	2.8
	91/92	4.1	1.93	0.115	5.9	2.8
IR blw. Tahlequah	80/81	8.7	2.45	0.475	11.9	4.7
	91/92	7.6	4.37	0.825	4.5	2.5
Baron Fork	80/81	4.6	1.59	0.152	2.2	1.2
	91/92	4.4	1.85	0.315	2.7	1.5
Flint Creek	80/81	4.5	1.54	0.041	3.1	2.7
	91/92	3.7	2.14	0.111	4.5	1.5
Sager Creek	80/81	6.9	3.13	1.008	2.4	1.1
	91/92	11.3	5.76	0.724	1.8	1.9

COD = Chemical Oxygen Demand (mg/L); TN = Total Nitrogen (mg/L); TP = Total Phosphorus (mg/L); TSS = Total Suspended Solids (mg/L); Turb. = Turbidity (NTU).

On the whole, averages from the two time periods are not very different, which corroborates that there has not been much of a trend over the years of the study. Again it should be mentioned that there was considerable variation within the two-year periods; therefore, mean values may be weighted by unusual events and differences in means may not be statistically significant.

Total nitrogen increased at all sites between the two periods. Although these increases were not generally of a large magnitude, the fact that they occurred at all sites leads to the conclusion that nitrogen loading has increased in the Illinois River (**Figure 4**).

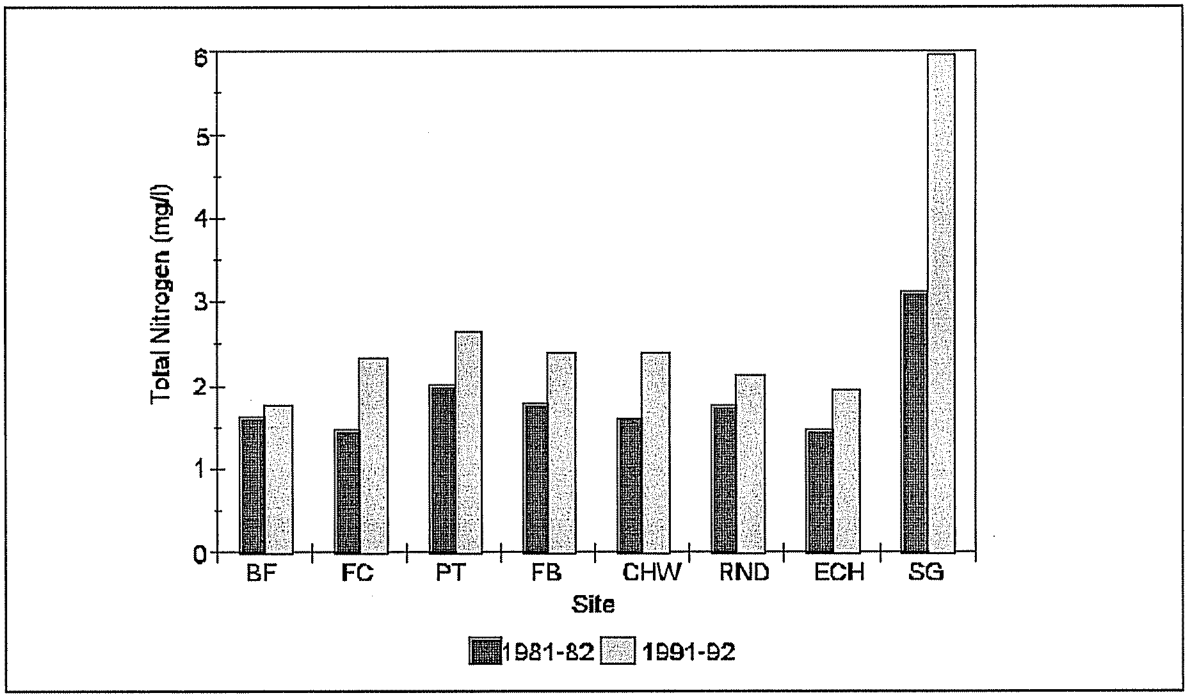

Figure 4. Comparison of Total Nitrogen Concentrations Between Time Periods.

There was no consistent increase or decrease in TP values among the sites. The most important observation to make is these values are all very high.

Of all the data, the increases in Flint Creek and the Baron Fork are probably the most alarming (**Figure 5**). The values from the samples collected the first year at Flint Creek were uniformly low and often below the detection limit of 0.005 mg/L. These values began to rise during 1982 but the two-year average is still quite low compared to other sites. The 91-92 values from this site are much higher and indicate a real change in phosphorus concentrations over the study period. A similar situation occurred in the Baron Fork. Seventeen of the first twenty-four samples collected contained phosphorus concentrations below the detection limit. The 91-92 values are greatly increased indicating a definite change in water quality in this river.

The concentration of TSS has not changed much over the study period with a fairly uniform distribution of increases and decreases. The values are similar down the course of the river with the exception of Camp Paddle Trails which is much higher than other sites. This is probably due to the dislodging of sediments from Lake Frances.

There has been a great deal of discussion concerning the loss of clarity in the river. From the data above it cannot be concluded that any observable changes have occurred between 1980 and 1992 (**Figure 6**). Drinking water is allowed a turbidity of

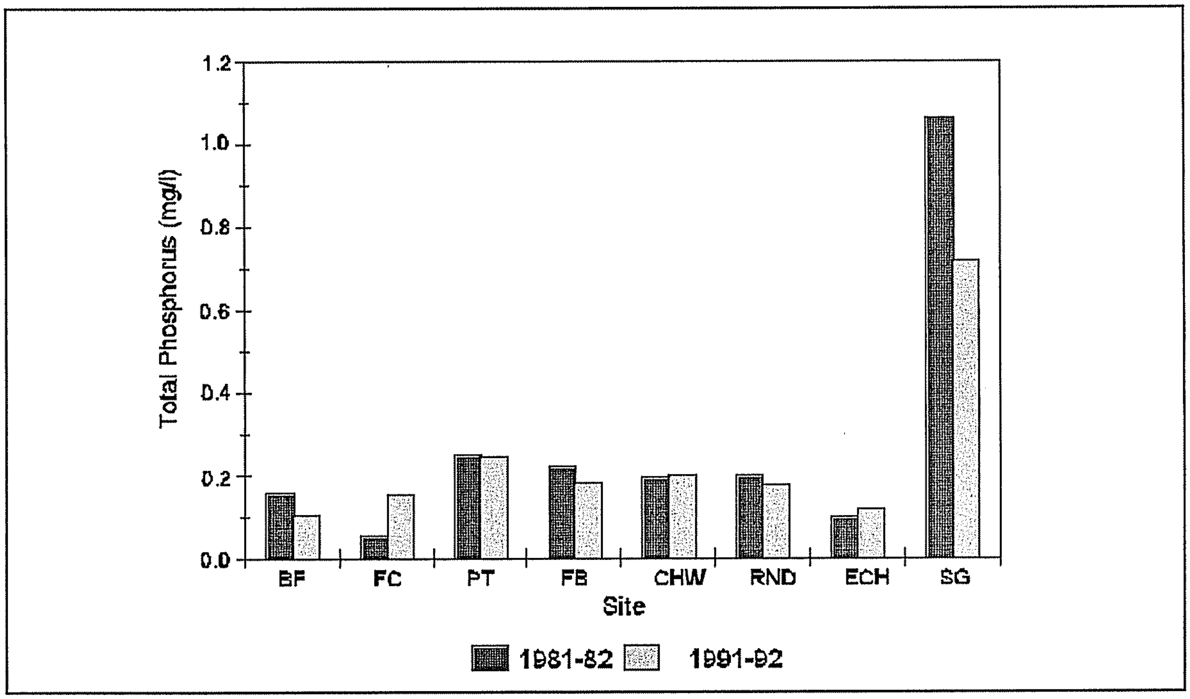

Figure 5. Phosphorus Concentration Comparison Between Time Periods.

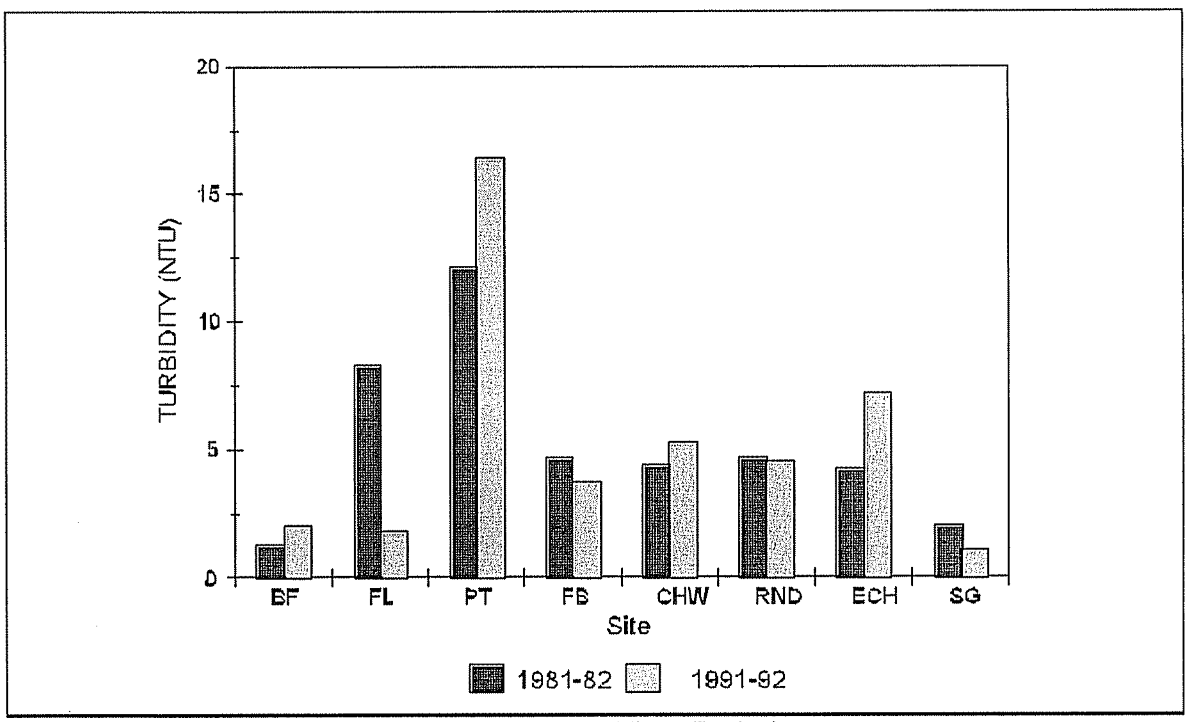

Figure 6. Turbidity Comparisons Between Time Periods.

1.0 NTU; therefore, since most of the changes are around this level, it is doubtful that observable (human eye) changes have occurred.

With such a large percentage of county residences relying on private water supply, the potential adverse affects of ground water contamination are readily apparent.

D. WATER QUALITY IN SMALL STREAMS OF THE ILLINOIS RIVER BASIN

Sixty-two small streams in the Illinois River watershed were monitored during 1990-1992 to determine the extent of nonpoint source (NPS) pollution occurring from land uses in small watersheds and to rank the watersheds as part of the BMP implementation process.

Streams were monitored on a quarterly basis under baseflow conditions and twice per year during runoff events. The data from these collections are summarized in **Table 12**.

Table 12. Summary of Water Quality in Illinois River Tributaries.

	TN (bf) (mg/L)	TP (bf) (mg/L)	TN/TP (bf) (%)	TN (re) (mg/L)	TP (re) (mg/L)	TN (re/bf) (%)	TP (re/bf) (%)
Minimum	0.18	0.001	8.51	0.24	0.004	0.41	0.31
Maximum	6.40	0.752	660	6.63	0.731	3.39	32.00
Mean	1.48	0.041	79	1.74	0.058	1.23	1.93*

TN = Total Nitrogen; TP = Total Phosphorus; bf = baseflow; re = runoff event
* = maximum value omitted (value = 2.41 with outlier)

It is generally agreed that nutrient loading in the Illinois River Basin is the major source of concern for both current conditions and long-term trends. Unfortunately, Oklahoma has no numerical standards for nitrogen or phosphorus. Guidelines exist in the literature but vary by author. Since the selection of a single guideline number would be somewhat subjective, it is probably best to discuss the data in terms of the range of opinion that exist in the literature.

Before the importance of nutrients at individual sites is discussed, it may be helpful to focus the discussion on the nutrient of greatest concern. The third column of data in the above table concerns the ratio of nitrogen to phosphorus found during baseflow conditions. This ratio is important in understanding the ability of the water to support algal growth and for management purposes as the addition of a limiting nutrient would accelerate algal growth. There is some range of opinion concerning the N:P ratio at which one or the other element becomes the factor responsible for limiting algal growth. The majority of research indicates that at N:P ratios of less than 10-16, nitrogen is the limiting nutrient, while phosphorus becomes limiting at higher ratios.

From column 3 it can be seen that the average N:P ratio is much greater than 16. In only 4 of 64 streams was the N:P ratio less than 16, and only one was less than 10. From these data it can be inferred that, as a basin-wide phenomenon, phosphorus availability is much more important in determining levels of algal growth than nitrogen; therefore, the discussion of nutrient levels will focus on phosphorus. It can also be inferred from this ratio and the high average nitrogen value that adequate nitrogen exists in these streams to support luxuriant algal growth. It should be noted that the factors concerning algal growth are much more complex than mere N:P ratios in that a number of micro-nutrient as well as physical factors are involved; however, N and P levels are often the controlling factors.

As previously mentioned, the maximum recommended level of phosphorus varies by author. In addition, the recommended level will also depend upon the nature of the receiving as well as downstream waters. It has been suggested that stream levels as high as 0.050 mg/L will cause no harm in the stream, although some authors put this value as low as 0.020 mg/L. The lower values are recommended when a downstream loading is a problem as occurs when a river is impounded. For the streams sampled in the Illinois River Basin it can be seen that, on average, baseflow phosphorus values approach the upper end of this range. Phosphorus values are distributed as follows:

Range (mg/L)	# of stream segments
<0.005 - <0.020	31
0.020 - <0.050	20
≥0.050	13

From these data it can be concluded that phosphorus is adequate to support rich algal growth in many streams of the Illinois River Basin, although it is inadequate in concentration relative to the amount of nitrogen present. This conclusion may seem somewhat contradictory as it suggests that phosphorus is both plentiful yet limiting. This type of contradictory evidence supports an assertion that algal productivity is closely tied to the abundance of some other nutrient. The identity of this nutrient is as yet unknown.

Historically, most attention has been placed on phosphorus limitation and as a result of this focus there is relatively little information suggesting maximum recommendations for nitrogen. A generally accepted upper limit for nitrogen for preventing the development of eutrophic conditions is 1.0 mg/L. The mean total nitrogen for all stream segments tested was 1.48 mg/L with the values being distributed as follows:

Range (mg/L)	# of stream segments
0.18 - 0.89	23
0.90 - 2.00	21
≥2.00	20

These data indicate that approximately two-thirds of the streams in the basin have nitrogen values which could result in eutrophic conditions. With twenty streams having values greater than 2.00 mg/L, it seems apparent that nitrogen levels are high enough to be a cause of concern for stream quality as well as downstream loading. These data also support the conclusion that nitrogen is not a limiting factor for algal growth.

It is also important to look at this data in terms of the relative concentration of nutrients under baseflow versus runoff conditions. As can be seen in the last two columns of **Table 12**, both nitrogen and phosphorus were elevated in runoff conditions. In some cases this was extreme while in others stream water appears to have been diluted. However, on average, nitrogen concentration increased approximately 23% while phosphorus increased 93%. Given the increased discharge during runoff events and the fact that the values gathered probably do not represent maximum event concentrations, it can be concluded that runoff of nutrients is an important contributor to stream and subsequently river water quality.

CONCLUSIONS

The primary conclusion that can be drawn from these data and comparing them to historical data is that water quality in the Illinois River was essentially similar between 91-92 and 81-92. There have been some changes, both positive and negative; however, for the most part these have been minor. The biggest changes that can be seen are in the degradation of water quality in Flint Creek and the Baron Fork.

A significant quantity of the nutrients in the river are coming from across the Arkansas border; however, significant contributions are occurring within Oklahoma. From the data it is obvious that sewage treatment plant discharges pose a major threat to river quality, although it should be mentioned that is difficult to assess the magnitude of this contribution relative to that from non-point sources based on these data. Contributions of nutrients within Oklahoma between Fiddlers Bend and Tahlequah must be almost entirely nonpoint source in nature.

A particular area of concern must be the contribution of nutrients and sediment from Lake Frances. Given the structural conditions which now exist, it is possible that almost all of the accumulated lake sediment will eventually be discharged into the river as it meanders across the lake bed unless corrective measures are taken.

Given the levels of nutrients in the river, it is not surprising that Lake Tenkiller is experiencing nutrient problems as demonstrated by accelerated eutrophication. The lake will continue to degrade at a rapid rate until these nutrient levels are significantly reduced.

One other area of concern is contamination of ground water from disposal of human and animal wastes. As will be illustrated in other sections of this document, rates of land disposal within the basin area very high. County residents rely on groundwater as their domestic supply as listed in **Table 13.**

Table 13. Housing Units and Residents with Private Water Supplies (Delaware, Cherokee, and Adair Counties).

County	Housing Units	Units w/ Private Supply	Residents w/ Private Supply (%)
Adair	7124	3477	8989 (48.8)
Cherokee	16808	8891	14849 (52.9)
Delaware	15935	4589	9500 (28.8)
Total	39867	16957	33338

E. ILLINOIS RIVER BASIN-- TREATMENT PRIORITIZATION FINAL REPORT

The OCC contracted with Oklahoma State University to use more sophisticated methods such as geographical information systems analysis to coordinate different types of data and prioritize subwatersheds in the Illinois River Basin (Sabbah et al. 1995). This report was an attempt to more closely coordinate land use and water quality information. The effort used the SIMPLE (Spatially Integrated Models for Phosphorus Loading and Erosion) modeling system developed by OSU to estimate watershed-level sediment and phosphorus loading to surface water bodies.

A section of the report dealt with identification and rank of potential phosphorus and sediment sources in the Peacheater Creek and Battle Branch Creek watersheds. Data layers were assembled including a digital elevation model, soil data, and current land use information assembled by the Oklahoma Cooperative Extension Service. Historical rainfall records (1950-1989) were used to run 40 one-year simulations. Long-term averages of runoff, sediment, and phosphorus loadings were estimated for each field and used to predict fields with high environmental risk potentials.

Average annual sediment loading from fields in the Battle Branch Watershed ranged from 0.00 - 0.88 Mg/ha (**Figure 7**). Predicted sediment loading was highest along the stream channel and from pasture, cropland, and hay meadows as opposed to woodlands.

Average annual total phosphorus loading to the stream ranged from 0 kg/ha - 9.34 kg/ha (**Figure 8**). Highest loadings came from fields with high soil test phosphorus levels and from cropped fields, pastures and hay meadows. Highest loadings were also seen in the headwaters of the watershed, as opposed to lower in the watershed, suggesting BMP implementation should focus on headwater areas, and then move downstream.

Average annual sediment loading from fields to Peacheater Creek ranged 0.00 - 0.96 kg/ha (**Figure 9**). Again, predicted sediment loading was highest along stream channels and from hay meadows and cropland.

Average annual total phosphorus loading to the stream in Peacheater Creek ranged from 0.01 - 34.88 kg/ha (**Figure 10**). Highest loadings came from hay and pasture land and were associated with high soil phosphorus levels. These high soil P levels likely result from application of poultry litter and perhaps from pasturing cattle. Again, areas providing the highest phosphorus loading are concentrated in the headwaters. This suggests BMP implementation should focus in headwaters before downstream areas.

Two critical ideas are supported by this report. The first is that much of the soil erosion in these watersheds happens along stream courses, and is probably associated with stream bank erosion. The second is that much of the phosphorus comes from the headwaters of the watershed, thus remediation efforts should concentrate in this area.

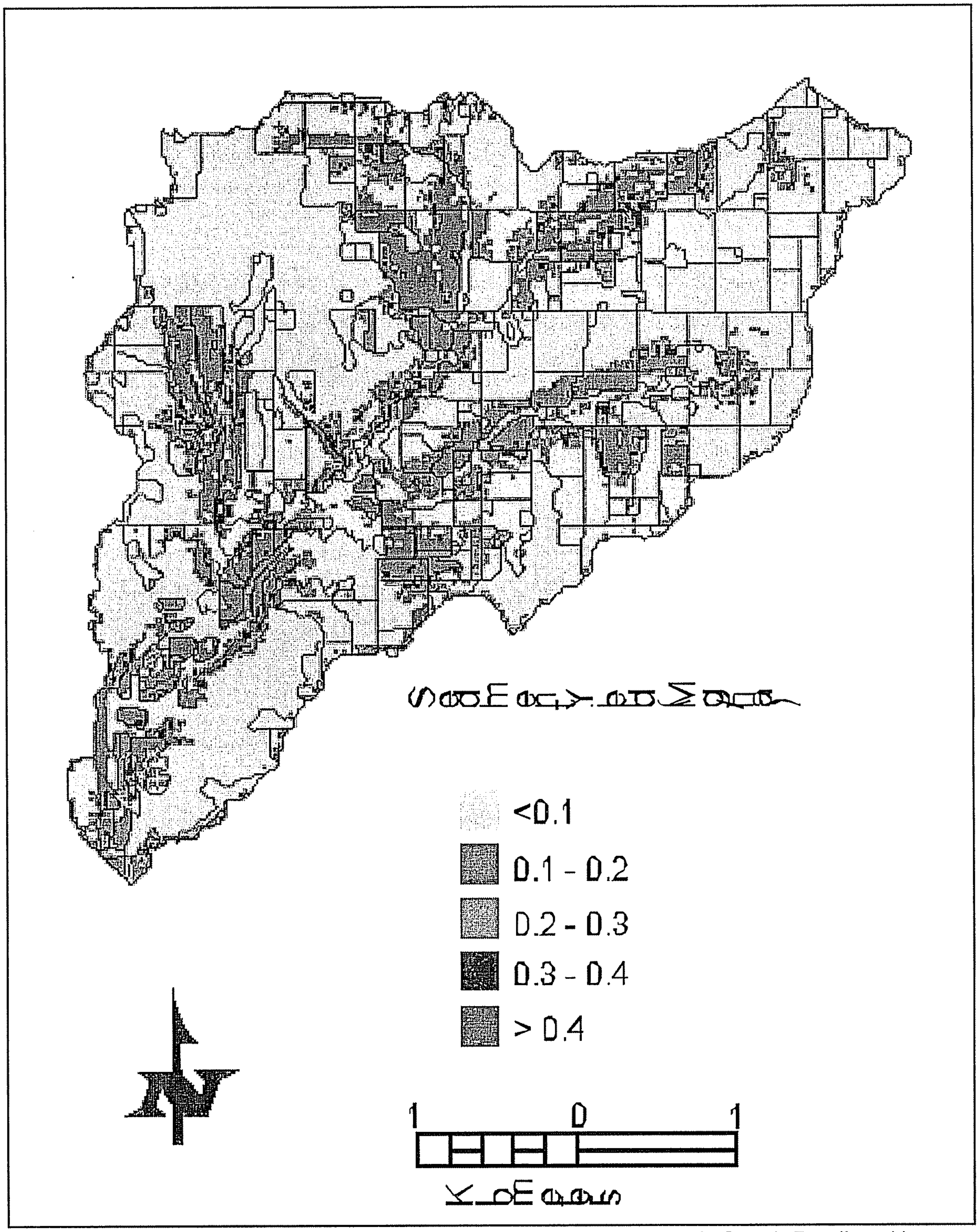

Figure 7. Average Annual Sediment Loading to Battle Branch Creek Predicted by SIMPLE.

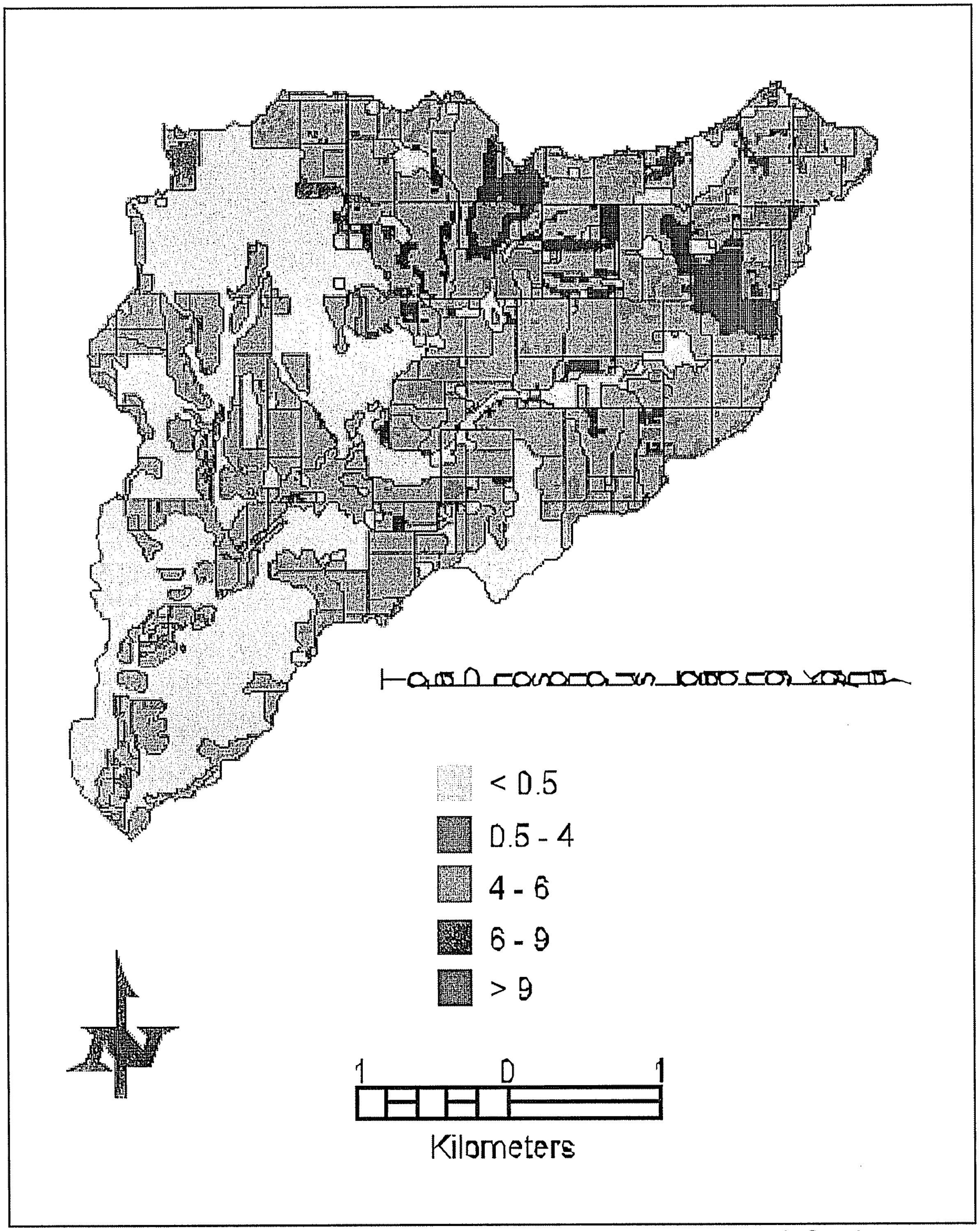

Figure 8. Average Annual Total Phosphorus Loading to Battle Branch Creek Predicted by SIMPLE.

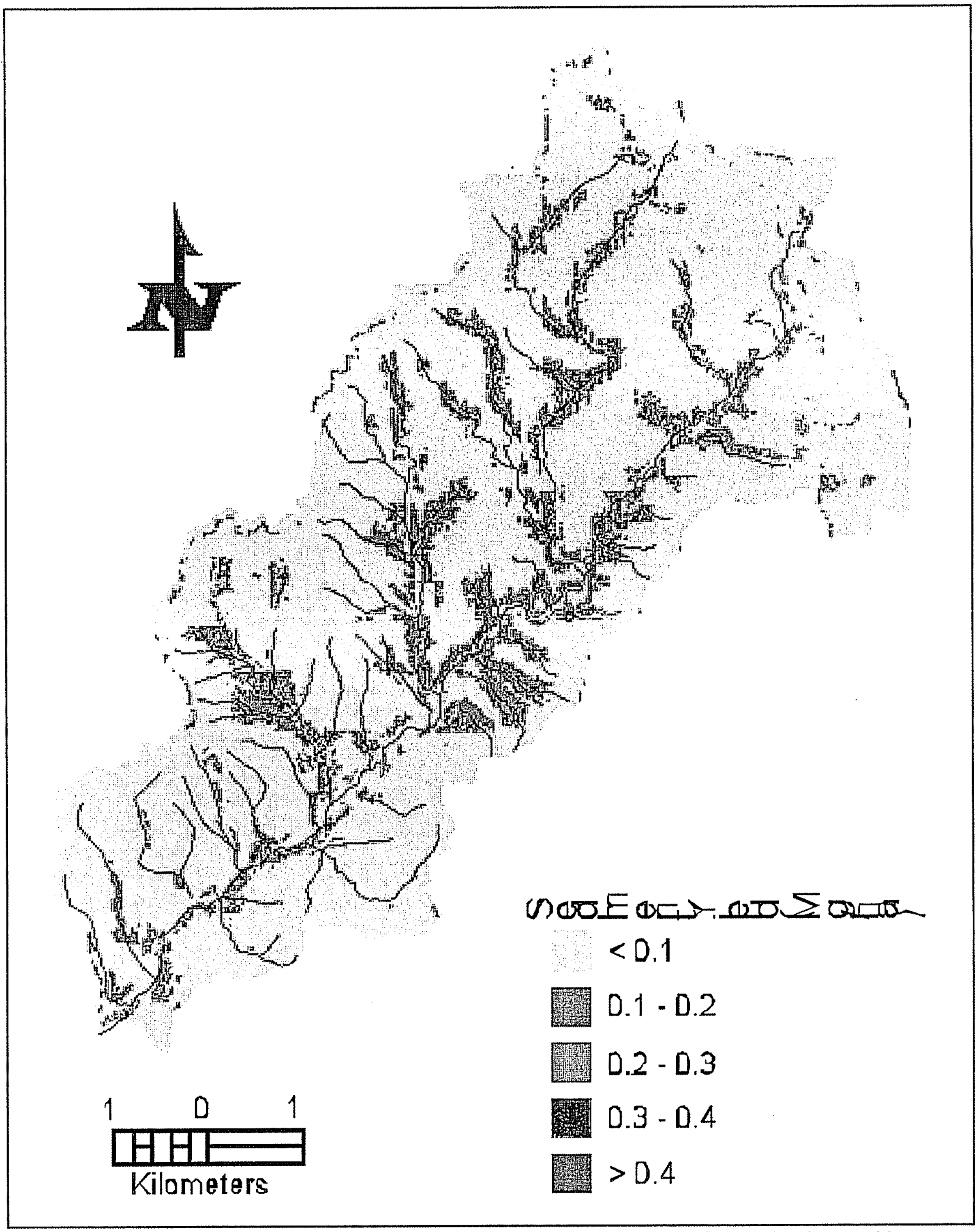

Figure 9. Average Annual Sediment Loading to Peacheater Creek Estimated by SIMPLE.

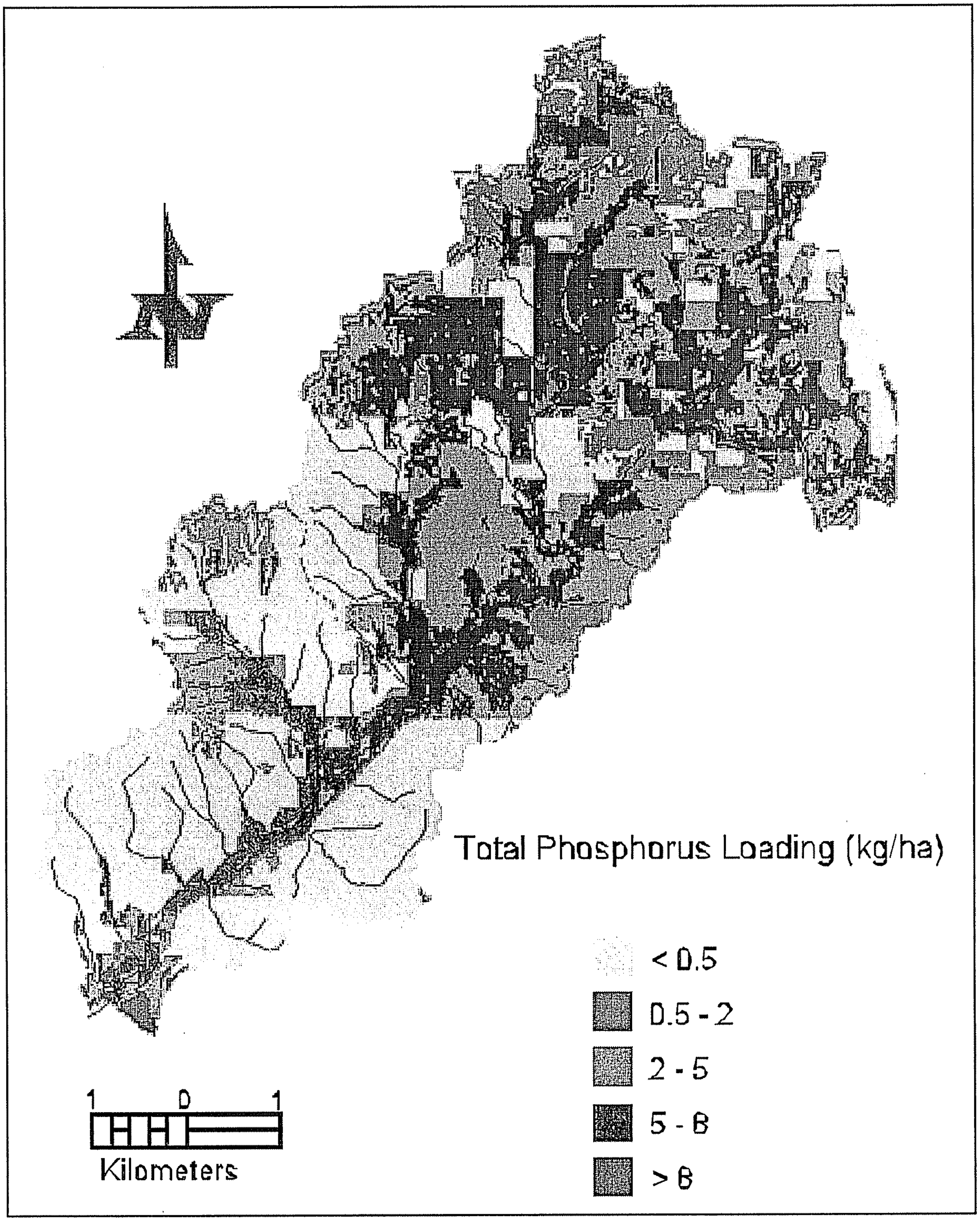

Figure 10. Average Annual Total Phosphorus Loading to Peacheater Creek Estimated by SIMPLE.

F. CLEAN LAKES PHASE I DIAGNOSTIC AND FEASIBILITY STUDY OF LAKE TENKILLER

The OWRB contracted with Oklahoma State University Water Quality Research Laboratory (OSU WQRL) to conduct an EPA Phase I Clean Lakes Study on Lake Tenkiller to diagnose the problems and recommend solutions. OSU WQRL studied the lake intensively between April 1992 and October 1993. Samples were collected at eight stations in and below the lake (**Figure 11**). Water Quality in the Illinois River and its tributaries was also analyzed for purposes of the study.

The study determined that water quality in Lake Tenkiller is currently showing signs of degradation. Symptoms included periodic algae blooms, excessive algal growth, and extensive hypolimnetic anoxia throughout stratified periods. The lake was classified as eutrophic based on nitrogen, phosphorus, and chlorophyll *a* concentrations (**Table 14**) which were excessive when compared to published criteria. These loads were predominantly derived from nonpoint sources during high flows and both point and nonpoint sources during low flows. These nutrient loads, especially the nonpoint fractions, have increased significantly since 1974 but have stabilized since 1985-86.

The study estimated the total nutrient loading to the lake, and partitioned that estimate by source. These estimates are seen in **Table 15**. These estimates represent loading to the lake from both Oklahoma and Arkansas. Distribution of the loading suggests the majority of the nutrient load is from nonpoint sources, although point sources contribute significant amounts. Analysis of the loading estimates also suggests the majority of loading is associated with highflow events. These conclusions are critical to the development of pollution reduction plans in the basin.

The excessive nutrient loads have increased algal growth and thus compromised water clarity throughout the lake and its tributaries. Nutrient limitation analysis indicated that the lake was phosphorus limited in the lower end (near the dam), variably limited (both phosphorus, nitrogen, and light) in the midreaches, and probably light limited in the headwaters. Based on these results, it was concluded that source control of phosphorus loading was the optimum management alternative. Accumulation of toxics in the lake water and sediments and resident fish did not appear to be a problem.

The study listed three alternative phosphorus control options and recommended initiation of a phosphorus control strategy in the basin. Those three options included:

1. No action.
2. Maintain current condition of the lake by preventing further increases in nutrient loads.
3. Reverse the accelerated eutrophication with more stringent phosphorus control measures.

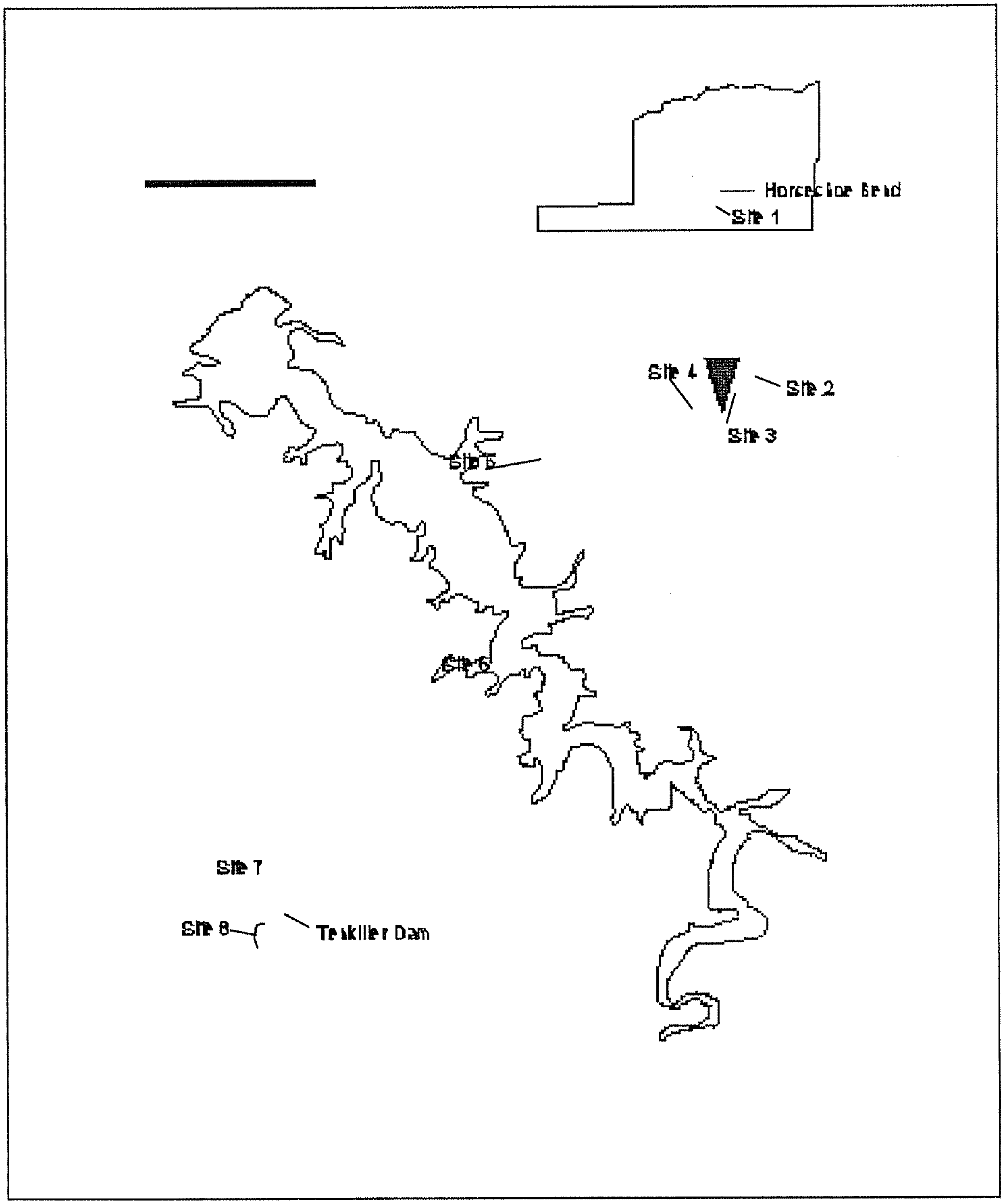

Figure 11. Clean Lakes Phase I Sampling Sites on Lake Tenkiller.

Table 14. Epilimnetic Nutrient Concentration Statistics of Lake Tenkiller.

PARAMETER	STATION	MEAN	MEDIAN	S	n
o-PHOSPHATE (mg/ℓ)	1	0.11	0.09	0.05	16
	2	0.05	0.04	0.03	18
	3	0.04	0.03	0.03	18
	4	0.04	0.03	0.03	18
	5	0.03	0.02	0.03	18
	6	0.02	0.01	0.02	18
	7	0.02	0.01	0.02	18
TOTAL PHOSPHORUS (mg/ℓ)	1	0.14	0.12	0.07	16
	2	0.08	0.08	0.03	18
	3	0.08	0.08	0.04	18
	4	0.08	0.07	0.04	18
	5	0.05	0.05	0.03	18
	6	0.04	0.02	0.04	18
	7	0.03	0.02	0.04	18
NITRATE (mg/ℓ)	1	1.27	1.18	0.56	16
	2	0.53	0.46	0.44	17
	3	0.49	0.36	0.45	18
	4	0.46	0.34	0.42	18
	5	0.38	0.21	0.38	18
	6	0.44	0.30	0.40	18
	7	0.47	0.30	0.36	18
TOTAL NITROGEN (mg/ℓ)	1	2.25	2.18	1.00	16
	2	1.45	1.16	0.75	17
	3	1.40	1.23	0.77	17
	4	1.34	1.17	0.66	17
	5	1.06	0.79	0.60	17
	6	0.97	0.74	0.59	17
	7	1.01	0.74	0.64	17

S = Standard Deviation; n = sample size

Table 15. Estimated Distribution of Nitrogen and Phosphorus Loads to Lake Tenkiller.

Source	Estimated Average Load at Horseshoe Bend kg/yr (%)		Estimated Low Flow Contribution at Horseshoe Bend kg/yr (%)		Estimated Medium Flow Contribution at Horseshoe Bend kg/yr (%)		Estimated High Flow Contribution at Horseshoe Bend kg/yr (%)	
	N	P	N	P	N	P	N	P
Background	550000 (23.9)	25000 (11.0)	35200 (22.8)	1600 (9.7)	208450 (23.9)	5225 (10.9)	306350 (24.0)	18175 (11.2)
Point Source	61605 (2.7)	12547 (5.5)	35793 (23.2)	7290 (44.1)	19406 (2.2)	3952 (8.2)	6407 (0.5)	1305 (0.8)
Nonpoint Source	1688980 (73.4)	190078 (83.5)	83345 (54.0)	7628 (46.2)	643869 (73.9)	38968 (80.9)	961795 (75.5)	143482 (88.0)
Total	**2300585**	**227625**	154338 (6.71)	16518 (7.26)	871725 (37.89)	48145 (21.15)	1274552 (55.40)	162962 (71.59)

The above three options are not discrete options but represent a continuum of management. After considering the feasibility and effectiveness of control measures, the report recommended a 30 - 40% reduction in headwater phosphorus loads be implemented as a short-term goal and a 70 - 80 % reduction as a long-term goal. Since both of these goals still indicated a significant risk of hypolimnetic anoxia, it was further recommended that re-aeration devices be installed in the tailrace to protect the downstream trout fishery.

The report recommended the following programs be initiated to attempt to reduce phosphorus contamination within the basin:

1. Voluntary switch to non-phosphate detergents by all lakeside residents and the cities of Tahlequah and Watts, OK and Rogers and Springdale, AK.
2. Implementation of best management practices upstream from Lake Tenkiller to minimize contributions of phosphorus in surface water runoff from agricultural fertilizer and waste and poultry litter applications.
3. Continue to work with point source dischargers, to the extent possible within the watershed, to minimize discharges of nutrients, including phosphorus
4. Establish a citizens monitoring group for basic water quality analysis and evaluation thus affording a more robust assessment of management effectiveness.

G. DETERMINING THE NUTRIENT STATUS OF THE UPPER ILLINOIS RIVER BASIN USING A LOTIC ECOSYSTEM TROPHIC STATE INDEX

The Clean Lakes Study determined that Lake Tenkiller was phosphorus limited at the lower end, variably limited by nitrogen, phosphorus, and light availability in the mid-reaches, and light limited at the upper end. However, it was unknown whether the Illinois River was limited by the same factors. One goal of this study was to determine which nutrients most often limit primary productivity in tributaries to the Illinois River.

The watersheds of three tributaries to the Illinois River were chosen based on availability of historical water quality data, similar land use, and similar size. These were Peacheater Creek, Tyner Creek, and Battle Creek. Although Battle Creek watershed was smaller than Peacheater and Tyner Creek watersheds, all had predominantly pasture and range land use (63 to 68 percent), and substantial forest cover (32 to 36 percent). The main difference in land uses among the three watersheds was the degree of anthropogenic activity.

The study used *in situ* nutrient limitation assays to estimate limiting nutrients in the three creeks. Six nutrient enrichment treatments were tested: 1. Nitrate - 5 ppm, 2. Phosphate - 5 ppm, 3.Nitrate and phosphate - 5 ppm, 4. Micronutrients - from Weber et al. (1989) at 200 times concentration, 5. Total nutrients, consisting of treatments 3 and 4, combined, and 6. Control- deionized water. Periphytometers were colonized in a run 0.3 m deep above a riffle for 14 days. Growth surfaces were protected from grazers with an aluminum screen. Assays were conducted in April and October 1995.

Results of the nutrient limitation assays are seen in **Table 16** and **Table 17**. Sample replicates numbers less than six indicate loss of samples. High flow events occurred in Battle Creek during both sampling periods, resulting in loss of replicates due to scouring. Comparisons of the treatment means was done using the Waller-Duncan K-ratio t test (α = 0.20). Results of t tests suggested that Battle Creek was phosphorus limited in the spring 1995 but limited by something other than nutrients during the fall, possibly light availability. Peacheater Creek appeared to be co-limited by nitrogen and phosphorus during both spring and fall sampling. Tyner Creek appeared to be limited by some factor other than nutrients during the spring and co-limited during the fall.

Conclusions of the report focus on the variable status of growth limiting factors in tributaries of the Illinois River. Clearly the creeks are impacted by nutrients, but also appear to be impacted by another factor, possibly light availability which would be affected by turbidity. The variability of growth limiting factors in these streams suggest they are primarily impacted by nonpoint source pollution. Nonpoint sources vary temporally as well as they do in substance and nature of pollution. A stream impacted by point sources would be expected to have a more consistent growth limiting factor between seasons. The findings of this report support conclusions of previous studies

Table 16. Chlorophyll *a* concentration for various treatments in Battle, Peacheater, and Tyner Creeks during the period of April 8 - 21, 1995.

Site	Treatment	Replicate Number	Mean Chl. *a* ($\mu g/cm^{-2}$)	Standard Deviation ($\mu g/cm^{-2}$)	Coefficient of Variation (%)
Battle Creek	N	5	1.16	0.64	60
	P	1	1.61	--	--
	N and P	5	1.67	0.60	36
	Micro-nutrients	5	0.48	0.76	160
	Total Nutrients	2	1.98	0.39	19
	Control	6	1.05	0.30	28
Peacheater Creek	N	6	1.05	0.42	40
	P	6	1.38	0.44	32
	N and P	6	1.61	0.72	45
	Micro-nutrients	6	0.35	0.10	28
	Total Nutrients	6	1.66	0.69	20
	Control	6	0.51	0.23	46
Tyner Creek	N	6	0.31	0.17	57
	P	6	0.20	0.08	42
	N and P	5	0.28	0.11	40
	Micro-nutrients	6	0.20	0.15	77
	Total Nutrients	6	0.33	0.10	29
	Control	6	0.21	0.14	65

that nutrients and sediment are problematic in the Illinois River Basin.

Table 17. Chlorophyll *a* concentration for various treatments in Battle, Peacheater, and Tyner Creeks during the period of September 20 - October 3, 1995.

Site	Treatment	Replicate Number	Mean Chl. *a* ($\mu g/cm^{-2}$)	Standard Deviation ($\mu g/cm^{-2}$)	Coefficient of Variation (%)
Battle Creek	N	4	0.33	0.05	17
	P	2	0.24	0.26	109
	N and P	4	0.63	0.36	56
	Micro-nutrients	2	0.21	0.09	42
	Total Nutrients	4	0.57	0.14	25
	Control	4	0.28	0.17	62
Peacheater Creek	N	6	0.55	0.18	33
	P	6	0.35	0.06	16
	N and P	6	0.55	0.55	49
	Micro-nutrients	6	0.23	0.23	24
	Total Nutrients	6	0.69	0.69	50
	Control	6	0.28	0.04	11
Tyner Creek	N	6	1.09	0.43	40
	P	6	1.06	0.20	19
	N and P	5	1.01	0.24	24
	Micro-nutrients	5	0.45	0.21	46
	Total Nutrients	6	0.98	0.40	41
	Control	6	0.55	0.19	35

H. ANALYSIS OF BANK EROSION ON THE ILLINOIS RIVER IN NORTHEAST OKLAHOMA

One source of increased turbidity in the Illinois River, its tributaries, and Lake Tenkiller and increased bedload in the Illinois River and its tributaries is believed to be streambank erosion. However, the magnitude of the contribution of streambank erosion had not been investigated until OSU and the OCC completed a survey of bank erosion on the Illinois River in 1996-1997. This project involved completion of several milestones:

1. Initial bank characterization, selection of banks for detailed study, and detailed characterization of selected banks were performed and reported in the Bank and Reach Characterization Report.
2. Long-term bank erosion was measured from aerial photographs and reported in the Aerial Photograph Erosion Analysis Report.
3. Short-term bank erosion was measured in the field at selected sites along the length of the river.

1. Initial Bank Characterization

In July 1996 193 bank segments along the length of the Illinois River from below Lake Frances dam to Horseshoe Bend on the upper portion of Lake Tenkiller were characterized. Data was generally collected only on eroding banks, however, several stable banks were characterized to provide a comparison. An effort was made to measure only significantly eroding banks, based on the area of bank erosion, generally exceeding 1000 ft^2. Data collected included length, height, angle, river position, location, material, vegetation type and percent cover, root depth and density, maximum water depth, bankfull depth, and percent flow in the near bank region under bankfull flow conditions. Banks were then grouped according to physical and vegetative conditions and hydrologic influence. At least one bank from each group (36 sites) was selected for detailed characterization. Selected sites were characterized with Rosgen Level III stream reach condition evaluation (Rosgen 1996). Twenty-three of the 36 sites were characterized as C4c-channels, 11 as C4, and 2 as F4. C4c and C4 channels are gravel dominated, slightly entrenched, gentle gradient, riffle/pool channels with high width/depth ratios. These channels, characterized by depositional features, are very susceptible to shifts in stability caused by flow changes and sediment delivery from the watershed. F4 channels have similar characteristics but are entrenched. Channel bars are common, and bank erosion rates may be high due to mass-wasting of the steep banks (Rosgen 1996).

2. Aerial Photograph Erosion Analysis

USDA-SCS 1:7920 scale aerial photographs taken in 1958, 1979, and 1991 were analyzed with a method modified from Brice (1982) to estimate long-term bank erosion. A complete set of aerial photographs for the Upper Illinois River was not available for 1958,